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# A Design Study of an Animated System for Representing Financial Ratios

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## ABSTRACT

Computer visualizations are all around us. In this paper we describe a design process in which we explore the development of a new visualization to aid managerial decision making. The ultimate goal of our design effort is to develop a visualization that allows for presenting most of the critical financial ratios used to describe a firm's activity on a single computer display and dynamically. In doing so, we hope to enable managers to develop holistic and intuitive appreciations of such matters as how a business changes through time, how the flows of resources in healthy businesses differ from those in trouble, and how decisions about one aspect of a business affect others.

## Keywords

Animation, information representation, visualization, decision making, accounting information systems

## INTRODUCTION

Much research provides information regarding decision making from both theoretical and empirical perspectives across several business disciplines, but a major concern in management remains how to even better understand and improve decision making (Shanteau, 2001). According to Libby (1981), there are three basic options for improving decision making:

- Educate the decision maker
- Replace the decision maker with a model
- Change the presentation and amount of information

From the design perspective, we are particularly interested in the third option. Research in information systems and cognitive science has indicated that diagrams can improve decision making or problem solving as compared to texts or tables (Benbasat, Dexter, and Todd, 1986; Dennis and Carte, 1998; Larkin and Simon, 1987; Umanath and Vessey, 1994). With the rise of computer-based visualization systems, animation and 3D modeling seem to be useful in enhancing the effectiveness and efficiency of information representation (Mayer and Sims, 1994; Rieber, 1990; Sukel, Catrambone, Essa, and Brostow, 2003; Tegarden, 1999), although some researchers warn that most of these optimistic results are not reliable (Tversky, Morrison, and Betrancourt, 2002).

As business information is often multidimensional and dynamic, which makes it difficult to communicate using traditional representations such as verbal descriptions or even graphics, we designed an animated visualization system, Business Animator. It represented the critical ratios and indicators related to a firm's financing and operating status and their changes over time. It adopted the system's view of accounting to treat the organization as a whole, as well as portrayed the flow of interrelated transactions. In this paper, we describe one particularly interesting moment in the designing process. The moment is bracketed by two versions of Business Animator, each associated with a set of laboratory experiments and observations. The first, which we will refer to as the "base version", tested a representation that we developed by thinking theoretically about how the Cycle Model might be modified to support solution of a bankruptcy prediction task described by Umanath and Vessy (1994). The second, which we refer to as the "refined version", was the result of making changes to the representation based on the performance and observation of subjects using the base version. This movement between using theory to

develop the representation and then observation to refine it has been typical in our design process. The moment we are describing in this paper is a particularly interesting one because it spans the point at which the potential of the representation became evident. The set of refinements that took place between the development of the base version and the refined version seems to have been adequate to providing a representation that was at once useful and usable for the task at hand.

The structure of the paper mirrors the process we went through. First we will review some visualization theories and empirical findings from the literature. After that we provide background on the specific problem that we chose to address. Then we describe the base version of our representation and the lab study that we did to test it. That is followed by a description of the refined version and test results associated with it. Finally, we discuss the process and how we see some of the future work that remains to be done on this design.

## THEORETICAL BACKGROUND

Distributed cognition theory dissolves the traditional boundary between human agents and their environments by arguing that cognition is not found within the mind alone but distributed across the internal mind and the external environment (Hutchins, 1995; Norman, 1993; Zhang and Norman, 1994). The basic principle is that the representational system of a distributive cognitive task includes a set of internal and external representations that together represent the abstract structure of the task (Zhang and Norman, 1994). To perform a cognitive task such as making a business judgment or decision, people need to process information distributed across both the internal mind and the external environment.

Internal representation, which is also called mental representation, is one of the earliest theoretical constructs of cognitive science. Contemporary cognitive scientists, particularly in contrast with behavioral psychologists, argue that internal representations are stored in the mind cause and explain behavior. As human cognition is unique in that it has become specialized for dealing with language simultaneously with nonverbal objects and events, many researchers have built models to simulate and explain how internal representations work. Based on imagery, dual coding theory suggests that memory consists of two separate and distinct mental representation systems: verbal and nonverbal. The assumption is that cognition is served by two modality-specific systems for representing and processing information concerning nonverbal objects and language (Paivio, 1991). Information is much easier to retain and retrieve because of the availability of two representation systems, and recalling information in the visual system is faster than recalling information in the verbal system because the visual system accesses information through synchronously, as opposed to the sequential access of the verbal system. Further, people process and recall pictures more fully than words and sentences.

External representations are “the knowledge and structure in the environment, as physical symbols, objects, or dimensions, and as external rules, constraints, or relations embedded in physical configurations” (Zhang, 1997). These are not simply inputs and stimuli to the internal mind as recent studies have found that external representations can significantly change the ease and even the nature of many cognitive tasks such as problem solving (Zhang and Norman, 1994), reasoning (Stenning and Oberlander, 1994), and decision making (Kleinmuntz and Schkade, 1993). Although external representations exist in many forms, one important class of external representations that make us smart is graphical inventions of all sorts (Card 1999). Tables and graphs are both used to represent large data sets. Many studies have explored the features of these two representations and the conditions under which each is superior in business decision making tasks (Benbasat 1986; Chan 2001; Vessey and Galletta 1991).

Whatever external representations we create have to link to the internal representations that people produce. Scaife and Rogers (1996) proposed three research directions from a distributed cognition perspective: the cognitive processing involved when interacting with graphical representations, the properties of the internal and external structures, and the cognitive benefits of different graphical representations. Defined as “the extent to which different external representations reduce the amount of cognitive effort required to solve informationally equivalent problems,” computational offloading is particularly applicable in research involved with the comparison among multiple representations. Psychology literature proposes a diverse set of dual process theories, with the generic format being to distinguish cognitive process into two systems: System 1 is fast, automatic and unconscious, while System 2 is slow, deliberative and conscious (Evans, 2003, Forthcoming; Stanovich, 2004; Stanovich and West, 2000). Many everyday decisions seem to involve intuitive judgments that people make with little or no conscious thinking. On the other hand, when people make much more complex decisions, they use the reflective decision making described in decision theories. Intuitive judgments seem to have System 1 characteristics, while reflective decision making seems much more like a System 2 process (Kahneman and Frederick, 2002; Kahneman and Frederick, 2005). As one stream of dual-process theory, the perceptual view of visual computing (Friedhoff and Peercy, 2000) brought a theoretical perspective to investigation of the way to reduce cognitive loading using visualization. Preconsciousness is meant to encompass all visual processes that do not seem to be manifestly consciously mediated. Preconscious processing is parallel, fast, automatic, and indefatigable, while conscious processing is serial, flexible,

continuous, and suitable for sophisticated analyses. Consequently, preconscious processing carries less cognitive load than conscious processing. This theory argues that “visualization is useful whenever the impact of an independent variable on a dependent variable can be perceived preconsciously” (Friedhoff and Peercy, 2000). In a successful visualization, conscious thinking can be directed at probing the relationship between an independent variable and dependent variable without distraction. Color, size, contrast, tilt, curvature, line ends, 3D, direction of lighting, movement, and stereoscopic depth are all properties that affect the earliest stages of visual processing. Therefore, we can facilitate the effective use of visualization by increasing the magnitude of the preconscious processing. A basic way to do this is to improve the visibility of the information embedded in the data (Domik, 1999). Animated visualization can take advantage of the sensitivity of the visual system to dynamic changes in various aspects of the data in order to invoke preconscious processing.

Another theory that attempts to build the connection between internal representations and external representations from the system’s view is cognitive fit theory. Vessey (1991) proposes a cognitive fit model based on three bodies of literature: human information processing, judgment under uncertainty, and behavioral decision making. It divides tasks into either spatial or symbolic based on the type of information used to facilitate the solution, then classifies representations into similar dimensions, such as graphical representations that emphasize spatial information and tabular representations that emphasize symbolic information. Cognitive fit theory argues that the effectiveness of problem solving is a function of the relationship between the problem-solving tasks and the problem representation, and concludes that when there is a fit of representation and task type, the representation leads to both quicker and more accurate problem solving. This finding has been supported and extended in many empirical studies (Dennis and Carte, 1998; Lim and Benbasat, 2000; Umanath and Vessey, 1994). However, while this theory emphasizes the importance of task features, it does not examine in detail the interaction between external representations and internal representations.

In a word, the prior literature provides a basis for optimism that an animated graphic representation will be useful given our objective of developing an understanding of the dynamics of an organization through time. Therefore, we propose that decision making accuracy will be higher when well-designed animations are used than when static graphs are used

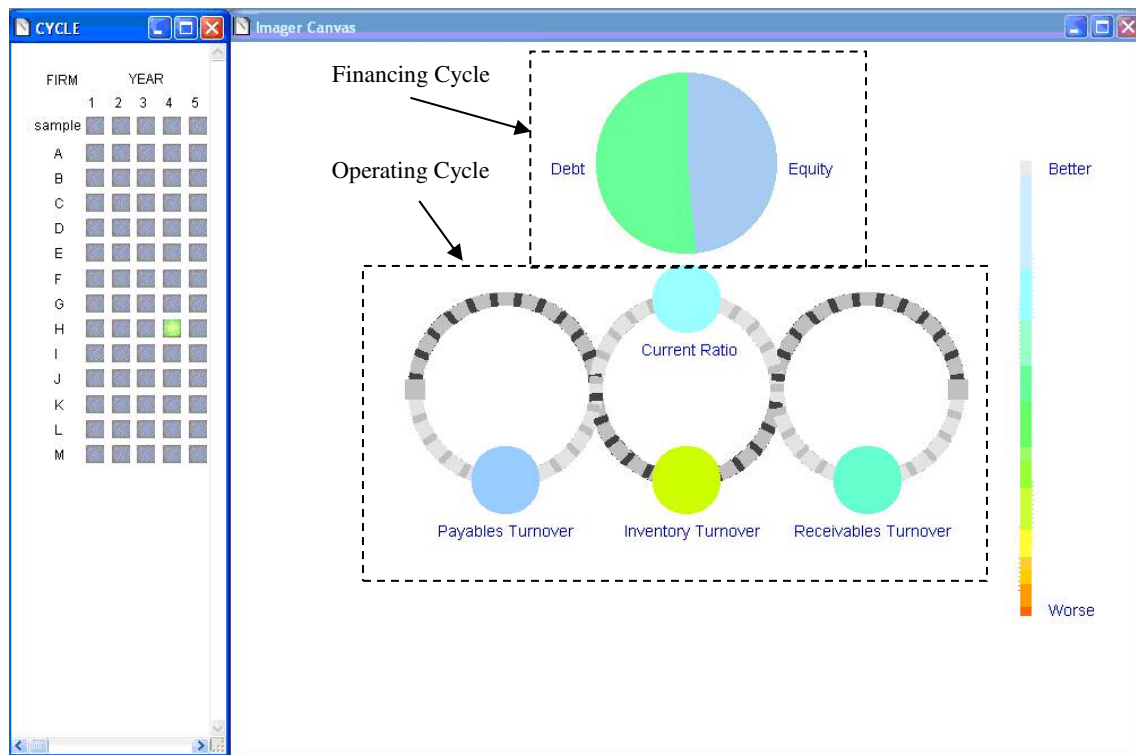
## DESIGN OF BUSINESS ANIMATOR

The Cycle Model was originally proposed by Boland (1983) and extended by Boland et al. (2008) to model a firm’s operating activities. The most basic version of which presents the operating cycle of a firm as three interacting cycles: an input cycle, a transformation or value-adding cycle, and an output cycle. A manufacturing firm provides the most accessible interpretation of these activities. The model assumes an existing business with the ability to purchase raw materials on credit. In the input cycle, a company acquires raw materials from its suppliers. In the transformation cycle, value is added to the raw materials through the manufacturing process to create inventory to sell to customers. The output cycle represents the sale of the finished goods to customers of the firm. This stylized representation, the operating cycle, represents the day-to-day operations of the firm. For a firm to be able to operate, however, requires capital investments in property, plant, and equipment and the funding to make those investments. The simple model shown assumes an existing firm with adequate resources for its current level of operations. The possibility of changing those levels of resources requires appending two additional cycles to the model, an investing cycle and a financing cycle.

With the advent of more powerful and accessible computer animation, the Cycle Model can be adapted to provide a dynamic representation of a firm’s activities utilizing control and display technologies developed for the real-time music industry (Max from Cycling 74). This dynamic version of the Cycle Model, named Business Animator, enables managers and analysts to develop an intuitive sense about the cycle model itself while exploring and visualizing how firms at various stages of growth, sustenance, and decay are affected by specific operating, financing, and investing decisions. The animation portrays temporality, allowing the theoretical construct momentum to be captured and depicted as the cycles change at differing rates.

### Base Version

In order to be compatible with the theoretical model and comparative to the previous empirical studies, we modified and extended the original Cycle Model in Business Animator as figure 1 shows. The major interface of Business Animator on the computer screen has two parts. At the left is a matrix of buttons that allows the user to choose which firm and which year is being viewed. Pressing on one of these allows the user to view that particular firm for the specified year. Ordinarily the user will move from year to year to examine the changes in a particular firm. At the right of the display is the visual representation of Business Animator with the color scale shown on the right. The features of the model are summarized in table 1 and the sections that follow.



**Figure 1. The Interface of Business Animator (Base Version)**

Financing Cycle		
	Size	Hue and Brightness
Left slice	Share of total assets financed by total debt the firm carries	Interest incurred on the firm's debt
right slice	Share of total assets financed by earnings from the firm's operations (retained earnings) and stockholders	Proportion of total assets financed by earnings from the firm's operations (retained earnings)
Operating Cycles		
	Speed of Path	Hue and Brightness
middle circle on the top		Current assets on hand after current liabilities are covered
middle circle on the bottom	Speed of selling inventory relative to all the firms	How quickly acquired products are sold
right circle on the bottom	Speed of collecting from customers relative to all the firms	How quickly customers pay for products
left circle on the bottom	Speed of paying suppliers relative to all the firms	How quickly suppliers are paid

**Table 1. Summary of the Graphic Features of Business Animator (Base Version)**

### Financing cycle

The pie chart at the top represents the financing cycle. It shows two sources of financing for the firm's assets: (a) debt and (b) equity that includes retained earnings and paid-in capital (common stock). Each component slice has two features: (a) size and (b) combination of hue and brightness. The slice size of each component represents the percentage of the firm's assets that come from that source. The hue and brightness of each component represent a related characteristic.

The size of the left slice represents how much debt the firm carries, while its color and brightness represents how much interest is incurred by its debt. A big debt slice in bright blue means that the firm carries a large amount of debt, but the majority of that debt is cheap (i.e., it carries little interest). On the other hand, a big debt slice in dark orange means the firm carries a large amount of more expensive debt.

The size of the right slice represents the share of total assets financed by earnings and stock investors. The hue and brightness represents the proportion of total assets financed by retained earnings from the firm's operations. The cooler and brighter the slice, the more the firm has been able to finance growth from its operations.

### Operating cycles

The three intersecting cycles at the bottom represent the operating cycle of the firm. Because this is a study of the retail industry, we use a store as an example. The left cycle is the input cycle, in which the store acquires products from its suppliers. In the transformation cycle located in the middle, value is added to the products by making the inventory available to sell to customers. The output cycle on the right side represents the sale of the products to the customers. The black path from left to right represents the movement of products over these three cycles. In the other direction, two joined grey paths represent the movement of money after the customers pay the company. The company then uses this money to pay its operating expenses, such as interest and the accounts payable owed to its suppliers.

The four small circles along the two operating paths represent activity ratios. The brightness and color of the middle circle on the bottom illustrate how quickly products are sold after being acquired. The speed of the black path represents the speed of acquiring and selling products relative to other firms. The brightness and color of the right circle on the bottom represents how quickly customers pay the firm for its products, while the brightness and color of the left circle on the bottom represents how quickly the firm pays its suppliers. The speed of the grey path going through the right circle represents the speed of receiving payments from customers relative to other firms, while the speed of the grey path going through the left circle represents the speed of paying suppliers relative to other firms. The brightness and color of the circle at the connection of two grey paths on the top of the middle cycle represents the excess of current assets over current liabilities.

The general rules in interpreting Business Animator are that brighter and cooler colors and faster movement are positive indicators. An intuitive way is to compare the color and brightness in Business Animator with the color scale on the right side. The color and brightness close to the bottom on the scale are negative indicators while the color and brightness close to the top on the scale are positive indicators.

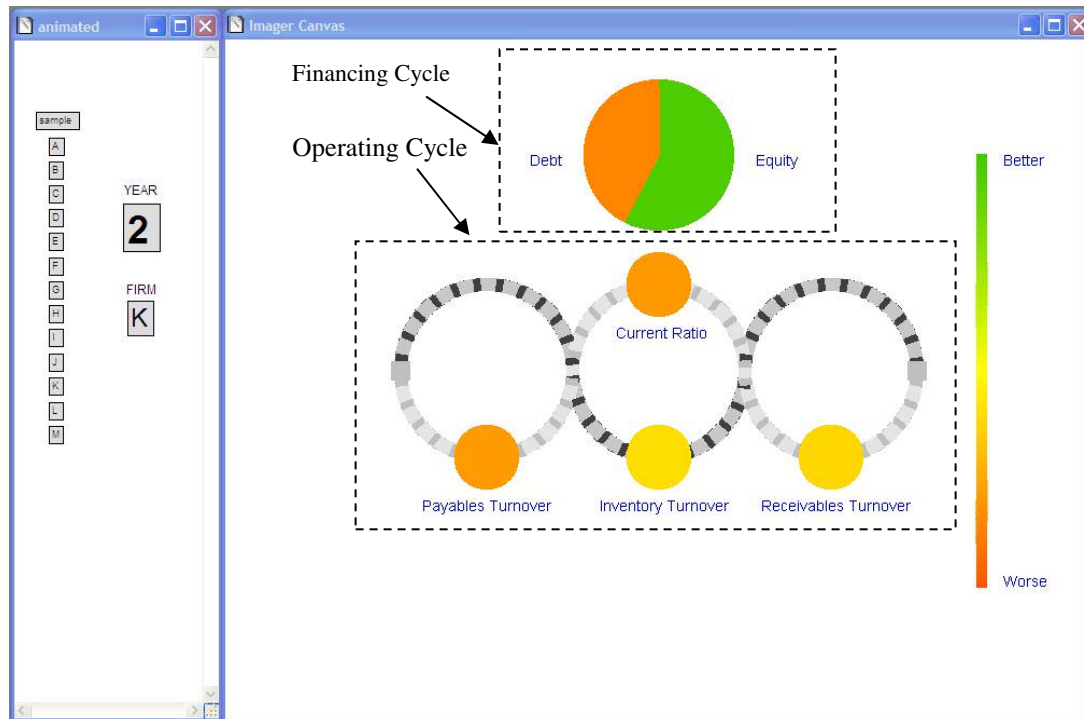
### Refined Version

Based on the interview and the statistical results from the experiment using Business Animator 1, subjects did not feel satisfied with the color scaled used. Most of the subjects thought the contrast on the color scale were not clear. For example, it was hard for them to notice the change from light orange and dark orange. Furthermore, some subjects could not compare each firm's performance across different years effectively, since they had to click the button on the left panel for each firm, which distracted their attention. On the other hand, it blocked the way of continuously thinking the changes over years. All these feedbacks motivated us to revise the Business Animator into a newer version.

In this version, as figure 2 and table 2 describe, we simplified the graphic features of Business Animator by removing the brightness dimension and making the color and movement speed of small circles on the operating cycles represent consistent turnover ratios. Furthermore, we set the color scale from red at the bottom to green at the top. The colors close to red are negative indicators while the colors close to green are positive indicators. This modification should have helped subjects more easily perceive the information from color as the red-green color scheme follows the traditional standard in business presentation (e.g., stock price and index reports, accounting and financial reports).

Animated effects are also enhanced by automatically showing the change of each firm over five years. On the left of the interface shown in figure 11 is a vertical list of buttons (ranging from "A" to "M") that allows the user to choose which firm to view. Pressing on one of these allows the user to view the smooth changes (trends) of that particular firm from the first

year to the fifth year. The two textboxes to the right show the user which year and which firm is being viewed. The example in figure 11 shows Firm K in the second year.



**Figure 2. The Interface of Business Animator (Refined Version)**

Financing Cycle		
	Size	Color
left slice	Share of total assets financed by total debt the firm carries	Interest incurred on the firm's debt, namely, debt service
Right slice	Share of total assets financed by earnings from the firm's operations (retained earnings) and stockholders	Proportion of total assets financed by earnings from the firm's operations (retained earnings), namely, self-financing
Operating Cycles		
	Speed of Path	Color of Circle
middle circle on the top		Current assets on hand after current liabilities are covered
middle circle on the bottom	How quickly acquired products are sold	
right circle on the bottom	How quickly customers pay for products	
left circle on the bottom	How quickly suppliers are paid	

**Table 2. Summary of the Graphic Features of Business Animator (Refined Version)**

In operating cycles, we used both path movement speed and color of circles to represent the turnover ratios for the current firm, as we found that the comparisons between the current firm and the average of the sample were not meaningful. Alington and Leaf (1992) found that redundant color is a critical factor in improving scores of men and women on difficult mental rotations tasks. In their second experiment, patterns were added beyond color, and subjects felt they could more readily discriminate with them than with those of the original stimulus. Therefore, in this version we decided to use two redundant graphic dimensions to represent turnover ratios.

## RESEARCH DESIGN

Research in visualization-based decision making often uses a comparative approach to study the differences among representations. The design of this study followed that tradition. We employed a holistic task—bankruptcy prediction. To succeed at this task, people need to process many ratios and temporal factors as a whole to assess the financial situation of a company (Vessey and Galletta 1991). Seven critical financial indicators (capital, total assets, current ratio, receivables turnover, inventory turnover, self-financing, and debt service) of thirteen firms adapted from previous research (Vessey and Galletta 1991) were evaluated by subjects over five time periods. In order to show a more complete structure of the organization's operational flows and shareholder equity and liabilities, an additional four indicators (debt, paid-in capital, retained earnings, and payables turnover) were also included. The dependent variable was judgmental accuracy. The independent variable was the type of representation (static graphs vs. BA base version vs. BA refined version). Static graphical representations were based on conventional financial market practice (NYSE: Daily Graphics) with financial statement balances as column graphs and financial ratios as line graphs. We include them here to compare the performance of Business Animator with classic benchmark.

## RESULTS

The experiment was conducted in three rounds at two universities following the same procedure. Of the 57 subjects who participated in the experiment, six did not complete the tasks successfully, so their inputs with missing values were deleted. As each subject performed the same tasks twice using different representations, a total 102 cases/observations were kept for further analysis. The ANOVA test showed there were significant differences across groups viewing different representations in accuracy ( $F(3,98)=2.743, p=0.047$ ). An independent sample  $t$ -test shows that subjects using the refined version of Business Animator made significantly more accurate judgment ( $t=-3.568, df=45, p<0.01$ ) than graphs, but not the base version of Business Animator ( $t=-1.060, df=45, p>0.10$ ).

## DISCUSSION AND IMPLICATIONS

The use of well-designed animations resulted in significant improvement in accuracy in bankruptcy prediction performance. Given a holistic decision-making task, subjects made more correct judgments when viewing an animated representation (Business Animator refined version) than when using tables or graphs. This study integrated theories from information systems, psychology and accounting to examine the roles of different representations in a classic business decision-making task. In information systems research, cognitive fit theory (Vessey, 1991) has been widely used to explain why graphs are sometimes better than tables for supporting decision making, but it does not systematically describe the link between external representation and internal representation. In another word, "fit" is not well defined. This research took distributed cognition theory as the foundation to consider cognition as a process distributed between individuals and artifacts rather than as a pure internal process. We also integrated dual coding theory to explain the internal representation and visual perception theories and to analyze the connections between internal and external representations. The conclusion was that one external representation outperforms others because it better invoked the preconscious connection with internal representations. The features in animations such as movement and color change increased the magnitude of the preconscious processing to facilitate the task performance, which was supported by current empirical findings. Furthermore, simplified color scale with sharp contrast and animated trend representation in the refined version significantly improved subjects' decision making accuracy, which indicated that the design features of animations had critical influence on the task performance.

The current findings tell decision makers they can be more effective when presented with data in a form that facilitates the link between internal and external representations. In another word, well-designed animated representations, such as Business Animator (refined version), for multidimensional accounting information (as opposed to the traditional animations such as flashing bar charts) can help practitioners to make decisions more effectively. The findings also provide some guidelines for system designers. Presentation of the dynamic flows in operating cycle and the proportions of assets on one single interface helps decision makers to get a better sense of data embedded in the numerical statements. People can easily identify the trend and underlying problems in the firms through animated changes regarding all the financial indicators over the years.



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